Lunar EVA Dosimetry: Microdosimeter-Dosimeter Instrument (PI Ziegler)

Completed Technology Project (2011 - 2013)

Project Introduction

1. AIMS. Cosmic radiation is the prime limiting factor of astronaut survivability. The objective of this research is to develop a radiation monitor for an astronaut's suit, which will determine radiation in real time, with an instant warning alarm in the space helmet, and with remote telemetry in the ship for real time advanced analysis. This new monitor will use radiation detectors about the size of the most sensitive human radiation cells, and also cell components such as the nucleolus (~6 μm). This will be accomplished using new semiconductor micro-dosimeters (SMD). The goal is to evaluate in detail the use of microdosimeters for various NASA radiation applications. This project started in 1 Jan. 2009, with Dr. Vincent Pisacane as the Principal Investigator (PI), and this report concludes the final year. Objective is to advance the state-of-the-art of solid-state microdosimeters (SSMD) to design, develop, and test an engineering model by September, 2013.

Aims include: 1.1 - Develop a bench-top system to advance the state-of-the-art of Silicon micro-dosimeters (SMDs) to incorporate proven advancements into the flight engineering model. 1.2 - Use the most advanced integrated-circuit technologies to make the most sensitive SMDs possible, allowing the measurement of the lowest energy radiation with high accuracy. 1.3 – Test the new micro-dosimeters with a wide variety of ion and neutron beams to evaluate their accuracy in a complex space environment. 1.4 – Evaluate the accuracy and advantage of microdosimeters designed to replicate human cells and cell components. Compare these results with those of more standard radiation dosimeters.

2. KEY FINDINGS. 2.1 Benchtop System – Obtained and analyzed SSMD spectra for NASA Space Radiation Laboratory (NSRL) beams (protons & heavy ions) to identify particle types, energies, and mass-to-charge ratios in the beams and produced by intervening materials. Reduced instrument noise levels near a factor of 10 during our National Space Biomedical Research Institute (NSBRI) funding period. Best noise measurements at NSRL with 200 feet of cable is ~0.3 keV/micron (~0.2 keV/micron-tissue). Compared SSMD spectra from our 1st generation sensors with silicon surface barrier detectors and also obtained spectra for neutrons, the most damaging particles. 2.2 Flight Engineering Model – The instrument developed in year 1 is called MIcroDosimeter iNstrument (MIDN)-II (MIDN-II) MIDN-II. We have designed an improved version, MIDN-III, reducing size and mass with an expanded set of remote commands. Its noise cutoffs is ~1 keV/micron. Continued development of our unique optical calibration system and applied for a patent in 2010. This provides a continuous end-to-end test and confirms the calibration or recalibrates the SSMD while in operation accomplished without a problematic radiation source. 2.3 Sensor Development – Prior observations were with the 1st generation SSMD sensors. A 2nd generation SSMD sensor was produced and tests confirmed performance using the benchtop and flight engineering instruments. 3rd and 4th generation sensors are now completed and extend the sensitivity of the microdosimeters by an order of magnitude.

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Table of Contents

2.4 Flight Opportunity – Completed a conceptual design to fit a NanoRacks configuration for the International Space Station (ISS) through the auspices of the Department of Defense (DoD) Space Test Program. Our system has been approved annually for several years for inclusion on DoD space missions. We were forced to decline a flight opportunity for a potential launch due to insufficient funds.

3. IMPACTS. Silicon micro-dosimeters (SMDs) have been shown to have noise levels better than that obtained with tissue equivalent proportional counters (TEPC) in space. SMD spectra for space protons will be able to obtain very low-lineal energy detection, a major goal of this research project. This was achieved by incorporating new integrated circuit technologies, not available in any past efforts. Recent measurements of SMD spectra with intense high-energy neutrons (~14 MeV), considered to be the most damaging particles in space, show that SMD can also operate in high-dose radiation fields for long time periods without failures. This establishes the radiation resistance of our SDMs, a major goal of this project. Recent measurements with SDM systems at the NSRL facility at Brookhaven National Laboratory (BNL) establish the practicality of using our new capability of identifying particle species: i.e., energy and charge-to-mass ratio responsible for specific individual events. Such measurements provide more stringent data for establishing quality factors and the accuracy of the transport codes and theoretical calculations, a major aim of this project. Recent measurements with SMD in a plastic phantom on a Heavy Ion Medical Accelerator in Chiba (HIMAC) beamline (in Japan) demonstrated the success of MIDN-III sensors for deep space missions by showing equivalent performance to TEPC instruments. Development of an end-to-end system test and calibration of an astronaut's personal SMD without the need for an ionizing radiation source is an important achievement. The final testing of MIDN-II sensors, and the design and highly-successful early testing of the MIDN-III sensors (probably final flight qualifiable personal SMDs) are important accomplishments. Development of WiFi communication and control of remote extravehicular activity (EVA) radiation sensor systems has been demonstrated, with real-time evaluation of radiation hazards.

4.0 RESEARCH PLAN - n/a (this was the final year of research).

Anticipated Benefits

To determine the risk from currently used radiation dosimeters requires knowledge of the species, energies, and frequencies of the radiation types or the frequency distributions as a function of linear energy transfer. The more frequently used passive dosimeters are also processed after the exposure and are not real-time instruments so the risk is inferred only after exposure. Microdosimeters are unique in that they can be used to directly determine the regulatory risk from radiation in real time when neither the species nor energies of the radiation are known. Thus it is a superior instrument for use in

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

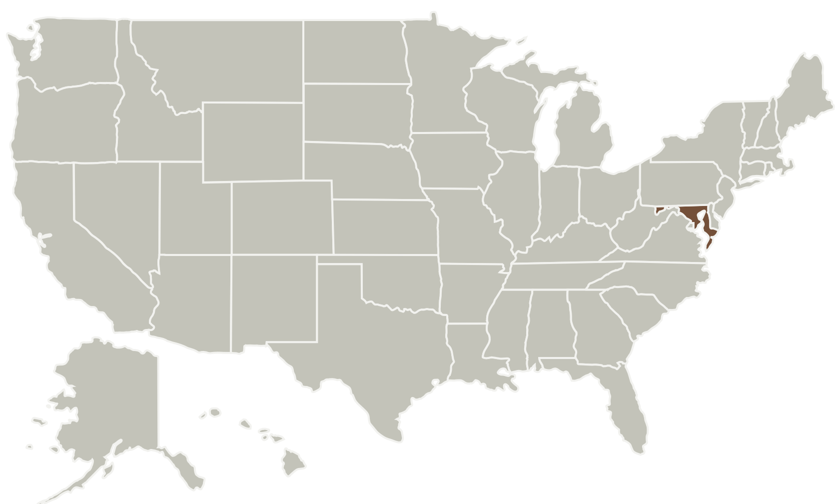
James Ziegler

Co-Investigators:

Marco Zaider
Quentin Dolecek
Francis A Cucinotta
Martin Nelson
John Dicello
Anatoly Rozenfeld

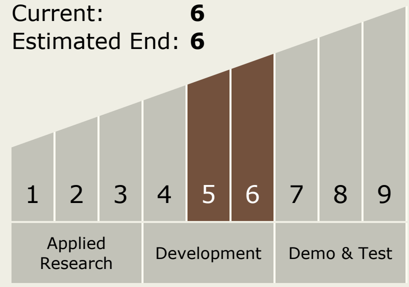
situations when the radiation environment is unknown and perhaps time varying. With sufficient investment in very-large-scale integration (VLSI) technology the solid-state microdosimeter can be integrated into a portable instrument. Since microdosimetry provides the regulatory risks from radiation exposure in real time, it can be beneficially used by first responders in emergency situations when there is uncertainty in the radiation risk. The microdosimeter can be used in nuclear power plants and other facilities with radioactive materials to provide risk due to exposure. It can also be used to detect contraband radioactive material; because of its compact size and potentially relatively low cost, it can be used in situations where large numbers of sensitive detectors are needed. Development of Silicon on Insulator (SOI) microdosimeters has a potentialy significant impact on applications to monitor the dose equivalent during proton therapy to reduce the possibility of secondary cancers generated in normal tissue by the radiation. Development of our calibration technique that does not use an ionizing radiation source will reduce the exposure of handlers of the microdosimeter. It will also eliminate the the cost of satisfying the regulations on certification of users and on the handling, shipping, and facilities.

Primary U.S. Work Locations and Key Partners



Technology Maturity (TRL)

Start: **5**
Current: **6**
Estimated End: **6**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └─ TX06.5 Radiation
    - └─ TX06.5.5 Monitoring Technology

Target Destinations

The Moon, Mars

Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Memorial Sloan-Kettering Cancer Institute	Supporting Organization	Industry	
United States Naval Academy	Supporting Organization	Academia	Chester, Maryland
University of Nevada-Las Vegas(UNLV)	Supporting Organization	Academia	Las Vegas, Nevada
University of Wollongong	Supporting Organization	Academia	

Primary U.S. Work Locations
Maryland

Project Transitions

October 2011: Project Start

September 2013: Closed out

Closeout Summary: NOTE: Former PI Vincent Pisacane retired as of 9/30/2011; James Ziegler is new PI effective 10/1/20 11 and project continues, per NSBRI. See Pisacane for FY2011 and earlier reports (Ed., 2/29/2012) The overall objective of this research project is to design, develop, and test a prototype solid-state microdosimeter (SSMD) by September 2013, sui table for use in the new NASA spacesuit and robotic operation on rovers, tool boxes, and spacecraft. The benchtop instrume nt continues to be used to develop and investigate improvements to the state-of-the-art of SSMDs. This past year the focus has been on development of improved ultra-low noise preamplifiers and new sensors. Radiation sources available at the U. S. Naval Academy (USNA) have been used to carry out the test protocols. The benchtop system has been expanded to obta in and analyze microdosimetric spectra for incident NASA Space Radiation Laboratory (NSRL) beams of both protons and he avy ions with identification of particle types in the beam, their energies, and their mass-to-charge ratios and those produce d by intervening materials. We carried out tests of our bench-top system with a neutron beam generated in the Nucleonics Laboratory at the USNA with favorable results. An improved version of the flight engineering model, MIDN-III, has been des igned and is nearing completion. It has a reduced footprint and mass and expanded remote command capability. We proces sed data sets obtained at the NSRL/BNL from our benchtop system, flight engineering model MIDN-II, and two Far West HA WK tissue equivalent proportional counters. Inter-comparisons of the observations agreed well and also agreed with Stoppi ng and Range of Ions in Matter (SRIM) and Geant4 simulations. These spectra have been added to our past data sets to up date our extensive library of microdosimetric spectra. We continued development our unique optical calibration system for a SSMD that permits continual end-to-end system test and calibration while the instrument is operational deployed. This is an alternative to using a radiation source that is problematic in a personal dosimeter and eliminates handling and shipping rest rictions and personnel and facility certifications required by international, federal, and local regulations. Our provisional pat ent application was superseded by a patent application. We have tested our second generation microdosimeter sensors with our bench-top and flight engineering instruments and compared our results favorably with those obtained at the University of Wollongong. We have completed testing new MIDN-III detectors, built with an SOI technology that reduces sensor noise over 10x. These sensors will allow accurate monitoring of protons of low energies, such as occur in a solar flare event. We c ompleted an initial conceptual design of our instrument to fit within a NanoRacks configuration for deployment on the Inter national Space Station through the auspices of the DoD Space Test Program. The NanoRacks configuration is modeled after the design of a cubesat. Our configuration would be 10 cm X 10 cm x 15 cm with the majority of the volume dedicated to a rechargeable battery power supply.

Stories

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/64500)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/64496)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/64489)

Articles in Other Journals or Periodicals
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Project Website:

https://taskbook.nasaprs.com